ANOXIA – When to break the ice?

Photo: Olav Noteng, Byneset Golf

Introduction

Ice encasement causes more dead turf in Nordic countries than any other winter stress.

Ice occurs most frequently in the transition zone between coastal and inland climate in Norway, Finland, Northern Sweden and Iceland.

We expect ice problems to become more common in the inland and at higher altitudes in the future, due to climate change related increases in temperature. Areas that previously had stable winter conditions will more frequently experience melting and freezing conditions during the winter, thereby substantially increasing the risk of ice encasement.

Long lasting ice encasement in Denmark and Southern Sweden is rare. We expect that these milder winter conditions will also become common further north, thus reducing ice problems on the south coast of Norway and Finland.

"When to break the ice?", is one of the most difficult questions for golf course managers because the economic impact of their decision is significant and the weather is unpredictable. The condition of the turf grass' under the ice is difficult to monitor and is dependent on many factors. There is also a considerable risk of physically damaging the turf when breaking the ice.

This text is short and the topic comprehensive. See the list of publications on the last page for additional information.

Summary

- Ice on golf greens and other short cut turf grass areas causes severe winter damages in Nordic countries;
- Long lasting ice encasement creates anoxic conditions, resulting in an energy depletion and the accumulation of toxic gases which can be lethal for plants;
- The turf's resistance depends on the grass species, but also on the organic matter content and porosity of the root zone; and
- The removal of ice can be crucial for grass survival.

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Sterf

A plants' life under ice

Anoxia

A solid ice cover will effectively prevent diffusion of gasses (gas exchange) between the atmosphere and the soil pores. The term "anaerobic conditions" is used to describe an environment that is free from oxygen. Living organisms under these conditions may be suffocated due to anoxia (=lack of oxygen).

We use the phrase "ice encasement" to indicate situations where the entire turf grass plant is covered in ice. When the soil is frozen, water from above will fill all of the pores and aggravate the situation.

Multifunctional golf courses? Photo: Olav Noteng, Byneset golf, February 2003

Respiration keeps life going

Plant roots and most microorganisms in the soil use oxygen for respiration. Respiration is a process that provides the cells with energy by controlled burning of their sugar reserves. Respiration is effective, and more than 50 % of the sugar energy is made available for the cell's activities.

Several phytotoxic products will be produced under anaerobic conditions. Photo: Albert Kjøsnes, Byneset GC

Respiration blocked – toxic chemicals produced

When the plant cells experience oxygen depletion (anoxia) they are not able to utilize their sugar reserves effectively. Respiration will be blocked and the plant is forced to turn on an alternative biochemical reaction (anaerobic respiration) that is far less efficient. The energy outcome is only 4 %. Sugar molecules are not completely transformed into CO_2 and H_2O, but are converted into organic acids and alcohols, which are harmful in high concentrations.

Ice encasement will also force soil microorganisms into anaerobic utilization of their energy reserves. Some of the by-products of anaerobic respiration have a very potent smell and are highly toxic to plants.

Result: Weak or dead turf

Winter kill from ice encasement is caused by:

1. Starvation
2. Intoxication

Plants that survive anoxia, naturally or with help from greenkeepers, have generally used up much of their sugar reserves. As such, they may be very weak and less tolerant to subsequent winter stresses such as low temperatures, excessive light or diseases.

Tiny cracks in the ice were enough to keep the aerobic respiration going and some plants survived. Photo: Agnar Kvalbein, Bodø GC, 30th June 2007.

Ranking of grass species and varieties for tolerance to ice encasement

NIBIO has tested green grass survival under different covers. Solid ice was one of the treatments. Photo: Agnar Kvalbein, NIBIO Apelsvoll

Genetics and acclimation conditions

Some grass species can survive under long lasting ice cover while others die after a few weeks. This characteristic is related to the species' ability to slow down their metabolism (some call it "go dormant") and to tolerate the toxic gasses that build up under the ice.

In addition to genetics, weather conditions during the autumn are also important. Clear days with temperatures around zero allow the plants to acclimate (prepare themselves for winter conditions). During acclimation, grass plants stop growing and store sugar reserves to be able to withstand increased darkness and other winter stresses.

Species for greens

A few experiments on golf greens have compared the species' ability to survive under anoxic conditions, but we will not publish a guaranteed number of days for each species. The reason is that the conditions vary significantly depending on air pores in the root zone, ice quality, acclimation conditions etc.

From weak to strong we rank:

- Annual meadow-grass (*Poa annua*)
- Rough meadow-grass (*Poa trivialis*)
- Red fescue (*Festuca rubra*) = common bent (*Agrostis capillaris*)
- Creeping bent (*Agrostis stolonifera*)
- Velvet bent (*Agrostis canina*)

To be a little more specific, on our experimental greens we have found that annual meadow grass rarely survives one month under solid ice while velvet bent showed no signs of fatigue after 100 days of ice encasement.

Species for tees and fairways

Long cut grass swards will often penetrate the ice and this creates micro-tubes that prevent anoxia around the grass crown. More often, we find winter kill from suffocation on fairways and tees where sheets of impermeable ice can more easily develop.

In addition to the species mentioned for greens we also use smooth-stalked meadow grass / Kentucky bluegrass (*Poa pratensis*) and perennial ryegrass (*Lolium perenne*) on fairways and tees. These two are at the opposite end of the scale. Ryegrass cultivars show only minor variations regarding winter stress tolerance and it is probably correct to rank the species as less resistant to ice encasement than most ecotypes of annual meadow-grass.

Smooth-stalked meadow grass is probably able to survive ice encasement better than creeping bent, but these two species usually grow under different soil conditions and are therefore difficult to compare directly. We find that smooth-stalked meadow-grass has a very strong resistance to all types of winter stresses.

Variety differences

Apart from the overall variation between species, there is always a certain variation between varieties within species. We have experienced that the variation is larger in red fescue and common bent than in creeping bent, velvet bent, perennial ryegrass, rough meadow-grass and smooth meadow-grass. In red fescue and common bent there are some Nordic varieties with tolerance to ice encasement comparable to smooth meadow grass and creeping bent.

Rain on frozen green in November created compact, transparent ice. By the end of January ice formed under snow is less transparent. Photo: Guttorm Ray Tuxen, Bærum GC.

Ice and soil quality

Access to oxygen is related to total porosity and pore size distribution in the soil and the permeability of the ice.

Compact ice is as transparent as glass while pores make the ice grey or white. Ice formed from clean water, like rain, is easy to crush, while ice from flooding water, polluted with calcium or other salts, is softer and more pliable.

Root zones that are well drained and have a good porous mat may contain plenty of oxygen to maintain aerobic respiration throughout the winter even if a compact ice layer has developed on the turf surface. These pores have no value as oxygen reservoirs if they are filled with ice.

The supply of microorganisms is also very important, especially when the soil temperature is above freezing. Microorganisms make up a significant amount of the total organic matter content and, as such, high organic matter content may lead to a rapid decrease in soil oxygen.

To conclude. The risk of dead turf increases when:

1. The ice layer is thick and has no cracks or pores.
2. The soil pores are filled with ice or water.
3. There is a high content of organic matter in the root zone.
4. The soil is poorly drained.

Temperatures and plant cell activity

When temperature is lower than -2 ˚C the respiration rate is small. Photo: Agnar Kvalbein

Under clear ice, the temperature fluctuations around the grass crowns can be more extreme than for openly exposed plants, especially on clear nights. Plants under such conditions are under a lot of stress, as they are exposed to both low temperatures and low oxygen levels.

Fortunately, bare ice is rare. Snow is an excellent insulator and only a couple of centimetres on top of the ice will keep the soil temperature between zero and - 5 ˚C even on very cold winter days.

The respiration rate of plants and microorganisms is strongly affected by temperature, The freezing point of plant cells is below zero and respiration therefore continues even when air and soil temperatures are below zero. We have seen that the sugar content in the plants depletes more quickly when soil temperature is above -2 ˚C. Oxygen depletion in the soil air also occurs when the temperature gets close to zero and the plant roots and microorganisms are not frozen.

When to break the ice?

Decision Tools

Temperature loggers installed in the turf canopy or thatch/mat layer can give useful information. The plants will respire during periods with temperatures over -2 ˚C, and if there is a solid sheet of ice on the green, you should be alert.

Your nose is the most valuable instrument for detecting anaerobic metabolism. Crack the ice, go down on your knees and check! A silage like smell or smell of foot-sweat means that oxygen is lacking. A strong smell of "rotten eggs" (hydrogen sulphide) tells that the soil microbes are active. This gas is toxic and should be replaced with fresh air as soon as possible.

In research we use an expensive instrument to analyse the carbon dioxide gas level under green covers, but it is not fit for surveillance of gasses in frozen soils.

It is recommended to take in turf samples for re-growth during the winter. It is difficult to drill out samples of turf from frozen greens. We use a concrete drill, and have experienced that breaking through the ice is the most difficult part. When the circle is drilled, the core can be broken or loosened with hammer and chisel. Take a sample from the least favourable location and compare it with a better (more up-hill part) of the green. After two weeks on the windowsill, you will get a good impression of how vigorous the turf is.

Before making up your mind

There are several factors that should be considered before your crew is ordered to break the ice.

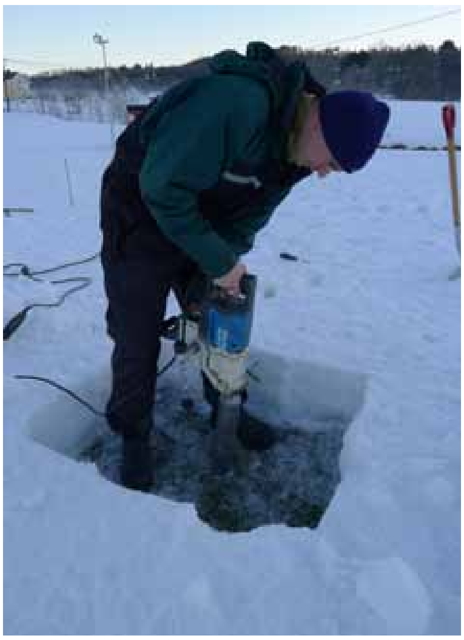
Grass species

The most important factor is the condition of the turf, which is first of all dependent on the turf grass species and the acclimation status of the plant. Canadian research has showed that there are considerable differences between ecotypes of Poa, but according to our research this species rarely survives more than 3-4 weeks of ice encasement If the ice has been present for a long time, you should spend your resources on a quick re-establishment rather than giving first aid to dead plants.

The other species, and especially the fine fescues, are worth fighting for because their survival time is limited, and their

A thermometer to monitor the green soil temperature gives useful information.
Photo Agnar Kvalbein, Messilän Golf

The course manager Oddbjørn Tidemann was happy to find the green in a good condition under the ice.
Photo: Agnar Kvalbein, Vestfold GC.



Monitoring frozen turf is challenging. Here a concrete drill is used to get a sample.
Photo: Agnar Kvalbein, NIBIO Landvik.

Grass regrowth tell show vigorous the turf is.
Sample in the middle from ice covered green.
Photo: Wendy Waalen, NIBIO Apelsvoll.

Full sunlight on transparent ice might be stressful. This fairway was completely dead. Photo: Olav Noteng, Byneset GC. February and April 2003.

It is a very bad sign when methane and hydrogen sulfide gas break through the ice. Photo: Ole Albert Kjøsnes, Byneset GC 2016.

The only positive about ice is that it makes it possible to use effective machinery. Photo: Magnus Barth, Fullerö GC.

recovery is very slow. Some bents are able to survive more than three months under ice. This gives you some more options for appropriate timing of the work.

Duration and density

It is difficult to monitor how long the ice actually has been encasing the grass crowns when it builds up under the snow. The density of the ice is also an important factor, and this can only be monitored visually by inspecting the ice under the snow in the field.

Root zone porosity

We have seen that new or well-maintained golf greens with no thatch layers and free drainage do not produce ice under snow to the same extent as older greens with low percolation rates. Golf course managers with local knowledge will know which greens are more susceptible to ice build-up.

Light or darkness

Is sunlight which shines through the ice damaging for plants? We think that full sunlight can be dangerous, but there are reports saying that some light through the ice can be beneficial for plants (cereals) as photosynthesis (that can occur at very low temperatures) will convert some carbon dioxide into oxygen and start aerobic respiration again.

Microbiology

Root zones with a high content of organic matter have a dark colour and a huge number of microorganisms. The microorganisms will use oxygen, and some of them are experts on living under anaerobic conditions. They can multiply, and may rapidly create the toxic gas hydrogen sulphide. The gas can break through the ice like small volcanos when the situation is acute. See picture.

The weather forecast

Scandinavian weather is unpredictable and sometimes you cannot wait for optimal conditions. Removing snow and exposing the turf to very low temperatures is risky. Plants that are exposed after removing or breaking the ice have a lower freezing tolerance. You may consider to blow snow over the green if there is a forecast for very low temperatures shortly after you have cracked the ice

Practical issues

Ideally, the ice should be strong enough to carry the load of a tractor or other machinery. Some liquid water under the ice makes it easier to separate the ice blocks from the turf. However, do not wait too long for good conditions. Physically damaged greens are easier to repair than partly dead greens.

How to break the ice?

Aerators with solid thick tines are most commonly used, but some heavy spikers have proven to be very effective as well. Undulated greens will be less damaged if you have narrow and flexible machines. The working depth should ideally be one cm less than the ice thickness, but the thickness of the ice normally varies a lot and some physical damage to the turf is to be expected.

Removing the ice?

It is usually not necessary to remove the cracked ice. Removing is a lot of work and the risk of compaction sometimes makes mechanization difficult.

There is of course a chance that the broken ice will re-freeze into a solid cover again, and this is probably why some greenkeepers with flat greens with elevated green surroundings (from frost heave) put effort into removing as much ice as possible. Others find that re-cracking is easier and causing less damage.

Melting is an alternative

Solar radiation provides a lot of energy in the spring, but most of this is reflected from the white snow or light-coloured ice. Sand-dressing on the snow/ice will absorb energy and accelerate the ice melting and can be an alternative to cracking on greens that are exposed to sunlight. Black sand from cast iron production or charcoal dust are also popular products for this use.

Several salts can be used to lower the freezing point of water and some have been used by greenkeepers on greens and by groundsmen on football pitches with success. Magnesium chloride is a popular product.

We have tested CMA (Calcium Magnesium Acetate) which melts holes in the ice without producing much water. The product is not efficient if the temperature is low, but grass showed no negative effects using rates up to 200g/m^2.

This machine has become popular not only for seeding. The vibrating solid tines can break the ice. Photo: Tor Mjøen

This ice was removed as a part of an experiment. The light green colour of the crushed ice indicates correct working depth. Photo: Agnar Kvalbein, Bærum GC, February 2008

CMA penetrates the ice, but is not very efficient under low temperatures. Photo: Agnar Kvalbein, Bærum GC, February 2008.

When all greens were dead in spring 2013, the course manager invited good colleagues to discuss "What did I do wrong and how do I repair this course?" Everyone learned a lot. Photo: Agnar Kvalbein, Vestfold GC.

Difficult decisions

When to break the ice is one of the most nagging concerns for golf course managers. It has caused many sleepless nights. Discuss the problems with good colleagues and agronomists, and always consult superiors to get their backing. Sooner or later you will make a mistake. In our part of the world you are not a greenkeeper before you have …. tried to save a green from suffocation without success.

Physical damage from ice breaking. Unfortunately this annual meadow grass was dead anyhow. Photo: Agnar Kvalbein, Bærum GC, April 2008.

Photo: Agnar Kvalbein.

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Related publications from STERF:

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- Grass species for severe winter climates
- Autumn preparation of golf greens
- Winter protective covers (Oct 2016)
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Scientific papers:

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